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A CONTRIBUTION TO THE BIOLOGY OF SEWAGE DISPOSAL. Pt. II.

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(With 27 Figures.)

Crude sewage in its passage through a filter, or at most say two such filters, each of some 6 or 8 feet high, may be changed into a clear and comparatively innocuous fluid. The organic pollution has thus been oxidised or "mineralised" in the process, and naturally one would presume, therefore, that in such filters the varying intensity of pollution, between the crude sewage and the purified effluent, would provide suitable conditions for the development of a range of organisms similar to that already given.

The relative absence of light within the filter, however, precludes any extensive development of algae, and therefore the dominant forms are almost entirely restricted to those of fungal and animal origin.

The inspection chamber (Figs. 1 and 2) enables ready examination of the filtering material to be made by simply pulling out the drawer at the desired level. The expanded metal work used to support both the contents of the drawers and the material in the bed around the drawers, offers a minimum resistance to the passage of the liquid through the filter. A small metal tray, 6in. × 8in., at the back of each drawer serves to intercept sufficient liquid—which is discharged by means of a small pipe *outside* the drawers—for chemical analysis without in any way disturbing the material of the filter or drawer.

When assigning, on a pollution basis, the position of any given aquatic or semi-aquatic organism it should be realised that in a sub-aerial position the organism can tolerate much more pollution than would normally be the case if totally submerged.

3.—Ecological Associations and Distribution of Organisms on Sewage Filters.

The character of the organisms occurring in any portion of a

sewage filter will, as previously stated, primarily depend upon the amount and character of the pollution. Apart from this primary factor the possible variations in conditions of aquatic ecology are remarkably few compared with those of terrestrial ecology, where a variation in the character and quantity of light, water, exposure to wind, acidity or alkalinity of soil, &c., may cause most remarkable modifications in the flora of a landscape.

The first of the above factors has been casually introduced already, and the general absence of light in a filter prevents the development of green (chlorophyllaceous) forms of life; a glance at the list of organisms, pp. 117 to 121, will serve to emphasise the fact that by far the greater number of B. mesosaprobes and oligosaprobes, *i.e.*, the organisms suited to purer liquids, are included in this category, and therefore the influence of light might be advantageous at this stage of purification. On the other hand it will be noticed that the organisms belonging to the most polluted liquids are chiefly bacterial, and do not therefore suffer from this absence of light. With regard to the former it is interesting to note that Hofer suggested the discharge of such liquids into large fish ponds. The partially purified sewage assisted the development of numerous algae, etc., and these in turn provided an abundant food supply for the fish. In this way it was found that the fish developed much more rapidly than under natural conditions, and their sale reduced to some extent the cost of treatment. In the presence of trade refuse partial treatment would be essential, and care would have to be exercised to prevent any untoward accident to the stock from the possibly poisonous character of these discharges.

Of the remaining factors the influence of the reaction of the crude sewage is perhaps the most important. Normally, a sewage effluent is neutral or very slightly alkaline to litmus, the amount of alkalinity may be very small indeed, requiring five or more minutes to effect any marked change of colour in the litmus paper. A solution of this character is well suited to the development of most bacteria and numerous other forms of life; whereas an acid liquid would be inimical to many, and occasion a change in the usual flora of a filter. Yet this influence can at most be only temporary, and the alteration is chiefly restricted to the primary processes of purification, because the liquid tends to become alkaline under treatment, but even if the effluent be acid the normal reaction of the great water masses is so uniformly slightly alkaline that the acid would eventually become neutralised, when the usual changes would then occur.

With such modifications as have been indicated, ecological associations in a sewage filter follow very closely upon the lines of

pollution intensity, and the remarks under the previous sections serve to outline the causes affecting such associations.

All that now remains is to describe such associations as are commonly encountered on a sewage filter. It must not be imagined, however, that any sharply defined zones can be distinguished; the change in the flora on passing from the top to the bottom is a gradual one, and it would be difficult to say where one zone ends or the next commences.

The upper portion of a filter receiving crude sewage contains chiefly those forms of life which belong to the Polysaprobes, and this

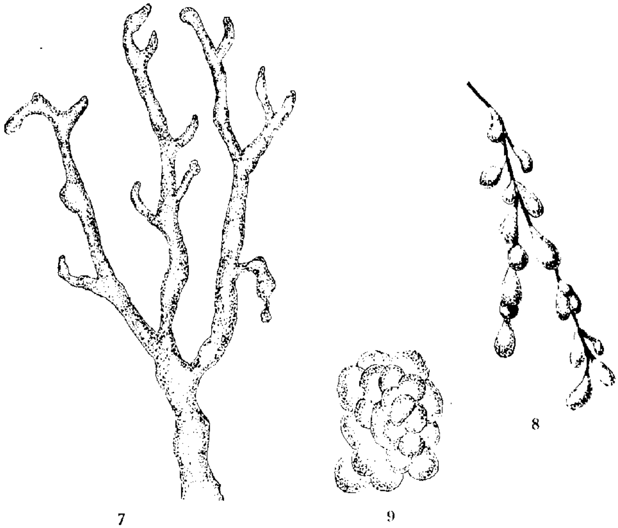


Fig. 7. *Zoogloea ramigera*, Itzshn. × 300.
Fig. 8. ,, ,, var. *uva*. × 1.
Fig. 9. ,, ,, var. *compacta*. × 500.
Del. M.J.

zone is especially prolific in these lowly organisms. The filter material rapidly becomes coated with a slimy or gelatinous growth of *Zoogloea ramigera*, which may be regarded as a large number of bacteria embedded in a gelatinous matrix (Figs. 7—9). This zoogloea is perhaps the most characteristic and important organism of this zone, and forms a suitable nidus for the development of fungal and other forms of life; whilst its gelatinous character enables it to directly absorb *soluble* polluting substances—as already described in Dunbar's adsorp-

tion theory. *Sphaerotilus natans*, *Beggiatoa alba*, *Thiothrix nivea*, *Chromatium okenii*, *Polytoma uvella*, etc., may also occur while species of *Saprolegnia* (Fig. 10) and other higher fungi are often brought down the sewers and develop on the top of the filter, together forming a fairly efficient strainer. The numerous hyphae which are to be found in this mass are not readily identified, but *Mucor racemosus* and *Mucor circinelloides* can be frequently recognised in subcultures.

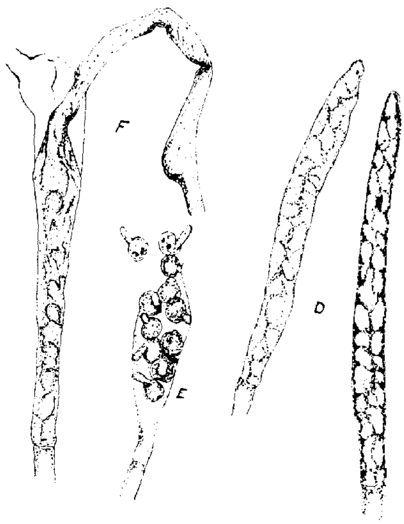


Fig. 10. *Saprolegnia* sp. found on sewage filter.
D. Division of concentrated protoplasm into spores.
E. Germination of spores while still within the cell (sporocyst).
F. New cell grown up through old. All × 300.
Del. J.W.H.J.

Botrytis vulgaris is also found in such situations; this fungus attacks cellulose very vigorously, and in one instance the growth was so dense that it very seriously obstructed a small water-course. Two characteristic chromogenic bacteria were also isolated from this material, *Magenta bacillus* and *B. violaceus*.

In some instances, however, where the discharges from modern industrial processes such as dyeing, carbonising and brewing have given an acid character to the liquid, the filter may then become covered with an orange coloured fungus, *Fusarium auriantiacum*, and tufts of *Oospora lactis* may become very abundant. The former

organism seems to be associated with the decomposition of carbohydrates, while the normal decomposition under neutral or slightly alkaline conditions is perhaps more intimately connected with changes in the nitrogenous contents of the sewage.

Some fungi are capable of existing under apparently very adverse conditions and *Sporotrichum lanatum*, Wall., was identified in material taken from the sill of a purification works treating dye waste. The

Fig. 11. *Sporotrichum lanatum*, Wallr. Showing numerous spores. × 500.
Del. J.W.H.J.

material, although deeply stained with the dye liquids, was still alive and rapidly produced spores which led to its identification (Fig 11).[1]

Agarics rarely appear on sewage filters, but *Hypholoma candol-*

[1] *Sporotrichum lanatum*, Wallr. (Fl. Crypt. Germ., ii, p. 276, 1833).—Tufts cushion-shaped, soft, elastic of loosely interwoven branched hyphae; conidia globose, small whitish, at length falling off. No measurements are given in the description of the species, but in the specimen from Yorkshire the woolly look is very characteristic; the spores are very abundant and are borne on short sterigmata often in groups near the tips of the branches, they measure up to 5 μ in diameter. The original substratum was decaying goosefeathers in Germany, it has also been found on paper in Holland.

leanum, Fr., has occurred on partially dried sludge in a settling tank, and often develops along with *Pilobolus* on the drying sludge.

The sub-aerial character of this zone markedly affects the range of organisms occurring in such a grossly polluted liquid, and organisms belonging to the mesosaprobes, such as *Phormidium autumnale*, which often forms a large bluish-black coating over a considerable portion of the surface and in summer dries up into blackish paper-like sheets, *Podura*, and the larvae of *Psychoda*, *Chironomus*, etc., while birds, flies, spiders, snails and worms often abound. In addition to these larger forms of animal life, amoebae, infusorians (*Paramaecium*, *Vorticella*, etc.) and rotifers may occur in large numbers.

The flora and fauna of a filter also exhibit certain seasonal variations, the most noticeable being characterised by a change in the colour of the filter surface, which is usually of a dirty grey or blackish slimy appearance. This change is generally attributable to the depredations of some form of animal life, *e.g.*, "*Podura*" (*Achorutes viaticus*) which devours the accumulated deposits of slime, etc., on the filter material and thus reveals the natural colour of the clean filter medium. This natural cleansing often commences at one point and gradually extends over the whole surface, and occurs chiefly in spring and autumn.

The flies found about such installations can scarcely be said to be restricted to any particular zone, but their eggs, larvae, etc., are naturally most numerous near the surface which is directly available for the deposition of eggs. Besides the two species of *Psychoda* which are described later, *Spathiophora hydromyzina*, *Camptocladius arterrimus*, species of *Chironomus* and *Trichocera hiemalis* are of fairly frequent occurrence. Hitherto, 109 mature spiders have been examined from three works near Wakefield and the results obtained show such a remarkable dominancy of relatively rare species that a detailed list of their occurrence seems justified. The figures within the brackets refer to males and females respectively:—*Erigone atra*, Bl., 4 (2, 2); *E. arctica*, White, var. *maritima*, Kul., 19, (7, 12); *E. dentipalpis*, Wid., 6 (3, 3); *E. promiscua*, Cb. 4 (2, 2); *Lessertia dentichelis*, Sm. = *Tmeticus simplex*, F.O.P.Cb. 60 (7, 53); *Araeoncus humilis*, Bl., 1 ♂; *Porrhomma thorellii*, Herm., 15 (2, 13). It will be noticed that the three dominant species with their percentage occurrences are:—*Lessertia dentichelis*, Sm., 55; *Porrhomma thorellii*, 13.6; and *Erigone arctica* v. *maritima*, 17.4; these three species together constitute 86 per cent. of the total arachnida observed. The two former species are of distinctly rare occurrence in Britain, while the occurrence of the latter variety at such a distance from the sea is also interesting. The *Lessertia* appear to belong to the variety *sublucicola*.

Arion hortensis is perhaps the most frequent slug, and is doubtless attracted by the large amount of organic matter deposited from the sewage. In contact beds the rather rare leech, *Trocheta subviridis*, has at times occurred in considerable numbers.

Besides the bacterial forms already enumerated, free-swimming species such as *Colon bacillus*, *Spirilla*, and other putrefactive bacteria may be present in large numbers; the number of the latter depends chiefly on the amount of putrefaction which has been allowed to occur. This brings us at once to the problem of septic and non-septic methods of purification, or purification by means of putrefactive changes on the one hand and direct oxidation on the other. Although in both instances the objective is the same, viz., the oxidation of the polluting substances, yet much of the objectionable nature of sewage disposal may be obviated by avoiding or restricting these primary putrefactive changes. Furthermore, recent experiments have shown that the putrefactive portion of the pollution is most readily absorbed by organised life and disappears first in the process of purification. Again the septic treatment—if it be septic—cannot be recommended on economic grounds as a much greater amount of oxygen is required to render innocuous the primary products of decomposition than would otherwise be the case if direct oxidation had been adopted.

Opportunities for the examination of the organisms at any considerable depth below the surface of the filter have until recently but rarely occurred. Such information as is at present available indicates that the zoogloeal masses rapidly become much less, while rotifers, paramaecia, nematodes and small earth-worms increase, and fungal hyphae are still present in less quantity than nearer the surface. In cases where the treatment is performed by two filters in series a number of algae have usually developed on the surface of the second, such as *Prasiola crispa*, *Stichococcus flaccidus*, *S. dissectus*, *Ulothrix variabilis*, *Myxonema tenue* (often with peculiar swollen cells); although "Podura" occasionally occurs, flies are relatively scarce. The deposit on the filter material loses its slimy character and becomes brown in colour. This zone does not appear to have any outstanding characteristic, but functions as an intermediate between the other two. The next zone does not support many living organisms, most fungi have entirely disappeared, bacteria are much less frequent, while numerous worms and a rich brown deposit of humus are the chief indications of the final stage. Algae would under normal conditions develop in such a liquid, but the absence of light within the filter precludes their development. The effluent channel, however, usually exhibits brown masses of small diatoms and green strands of algae. *Van Heurckia*

rhomboides v. *saxonica* (Rabh.), G. S. West, *Gomphonema parvulum*, *Acnanthes lanceolata*, and var. *dubia* are most common among the former, while species of *Mougeotia*, *Myxonema*, *Cladophora*, *Vaucheria*, *Rhizoclonium* and *Ulothrix* are of frequent occurrence among the latter. At times grey patches of *Carchesium lachmanni* may appear, and more especially if the effluent is occasionally of doubtful purity. It will thus be readily seen that the flora and fauna of a water-course provide indelible evidence of the *general* character and purity of the liquid in that water-course.

The following table shows the chemical changes in a tank effluent as it passes through a filter :—

WAKEFIELD SEWAGE WORKS.

(Results expressed in parts per 100,000).

Monthly Average Analyses of Samples taken from Inspection Chamber.

	Chlorides (as Cl). Tank Effluent	Oxygen absorbed in 4 hours from N/80 $KMnO_4$ Effluent taken at depths in feet of							Nitrates and Nitrites (as N). Effluent taken at depths in feet of						Alkalinity (as CaO).* Effluent taken at depths in feet of						
		Tank Efflt.	1	2	3	4	5	6	1	2	3	4	5	6	Tank Efflt.	1	2	3	4	5	6
1913																					
October	17·7	5·11	4·57	3·35	3·20	3·14	2·71	2·21	—	·23	—	·38	—	·64	2·7	1·5	trace	nil	nil	nil	nil
November ..	19·8	6·01	5·76	2·69	2·95	3·33	2·81	2·26	—	·29	—	·46	—	·56	2·8	1·1	trace	nil	nil	nil	nil
1914																					
January	—	4·37	3·12	2·05	1·67	1·36	1·45	1·42	·47	·59	·78	1·37	1·18	1·29	3·0	1·1	trace	nil	nil	nil	nil
February ..	—	5·10	2·73	2·78	2·08	1·65	1·07	1·18	·55	·58	1·02	1·03	1·22	1·22	3·1	·6	·5	trace	nil	nil	nil
March	13·6	5·03	2·00	1·64	1·69	1·27	1·03	—	·67	—	1·12	—	2·20	—	2·7	trace	nil	nil	nil	nil	nil
April	15·4	5·16	2·89	2·02	1·76	1·25	1·22	—	—	—	—	—	—	—	—	—	—	—	—	—	—
May	21·6	4·90	3·10	—	2·40	1·69	1·33	1·22	—	—	—	—	—	—	—	—	—	—	—	—	—
June	20·0	4·54	3·09	1·97	2·14	1·78	1·45	—	—	—	—	—	—	—	3·4	1·8	·3	nil	—	—	—

* These figures indicate the caustic alkalinity due to added quick-lime only, and the nil results do not in any way influence the statement on page 128, as the liquid is still slightly alkaline to litmus.

4 Some Noteworthy Dominant Organisms Occurring on Sewage Filters.

(a) The Sewage-Fly or Moth-Fly (*Psychoda*).

The great increase in late years in the number of percolating filters for sewage purification has drawn attention to the troubles arising from their use, of which perhaps the chief is the nuisance caused by flies, which breed in the interstices of the filters.

12

13

14

Fig. 12. *Psychoda phalaenoides* (L). (female). Showing the characteristically jointed antennae, but no wing spots.
Fig. 13. *Psychoda phalaenoides* (L). (female). Much less hairy than Fig. 14.
Fig. 14. *Psychoda sexpunctata*, Curtis. (female). Showing some wing-spots, while others have almost been obliterated. All × 10.
Phot. J.W.H.J.

All percolating filters serve to some extent as a breeding ground for flies of various kinds, and in consequence they are the favourite haunts of swallows, wagtails, and other small insectivorous birds. In the majority of cases these flies, although varying in numbers according to the season, are not so numerous as to make their presence obnoxious,

at least beyond the confines of the sewage works. In other cases, where circumstances favour their development, they may appear in myriads at certain times of the year and be carried by the wind into inhabited neighbourhoods so as to give rise to an intolerable nuisance.

This nuisance may be looked upon as causing annoyance: (*a*) from the presence of the insects in such numbers in and about dwellings, where they are troublesome by reason of the personal discomfort they produce, and although not all persons are affected, it seems certain that in some cases the flies or perhaps the readily abraded hairs produce great skin irritation; (*b*) by their unsightly appearance, attaching themselves as they do to any object, particularly any moist surface; and (*c*) by their settling upon articles of dress and food.

The flies which are chiefly responsible for this nuisance belong to the genus *Psychoda*, and appear to be chiefly restricted to the two species *Ps. phalaenoides* (L.) and *Ps. sexpunctata*, Curtis[1] (Figs. 12—14.

When a filter in which the top layer consists of large pieces of filtering material, or which has dry built side walls, is examined during warm weather these flies, their pupae and their larvae, are to be found in the interstices of the material. If a piece of material be removed from the top of the filter, the dry portion of its under surface is usually covered with the mature insects. These are small active brownish-grey hairy flies, with transparent wings and long and characteristically jointed antennae. The wings are longer than the body, which they completely cover, and when at rest have a characteristic roof-like slope. Both the body and wings are densely covered with hairs, which give the fly at first sight the appearance of a small moth, and hence the name *Psychoda* (moth-like). The hairy covering on the wings and body offers considerable resistance to flight, and consequently movements are chiefly restricted to running, hopping, or short flights. The fly was very common in the old-fashioned unattended street urinals, flitting from slab to slab or running about their edges. It has a marked predilection for moist decaying animal and vegetable matter, and for malodorous moist situations in general. It is sometimes found in swarms in hot-houses and about open drains in spring and autumn. It must not, however, be concluded that *Psychoda* is restricted to polluted areas, for it occurs in the woods and forests far away from human surroundings.

There are two distinct species, one lighter coloured and larger than the other, and recognised when examined with a pocket lens, by a

[1] This species is apparently identical with *Ps. alternata*, Say, the latter name being some 15 years older should replace the above.

larger development of small hairs on the body and wings, and by dark spots which occur at the end of a vein or nervure, on the periphery of both wings. Thus *Psychoda sexpunctata* is distinguished from the other, which is known as *Psychoda phalaenoides*. It will be sufficient, therefore, to describe one species only, noting the points of difference which the other presents.

Psychoda sexpunctata, Curtis, like most insects goes through four different stages in its life cycle, viz., egg, larva, pupa, and imago.

The eggs (Fig. 15) are deposited in moist surroundings, and these of course are available in a sewage filter.

As is common among the Nemocera, the eggs are stated to be irregularly disposed in a gelatinous mass of indefinite shape attached to some solid object; the egg mass measuring 1 to 2 mm. across and containing some 15 to 40 eggs. In one case, however, an egg mass contained over 100 eggs, while in others the eggs were deposited either singly or in twos and threes.[1] A single insect was found to contain over 100 eggs. The individual eggs are small (0.2 to 0.3 mm.), sausage-shaped, opaque, and filled with yolk granules. Hatching takes place within a few days after deposition; the time naturally varies with the temperature, and during summer weather this occurred within 48 hours, while in October five days were required. The eggs are usually laid amongst moist decaying organic matter, which is thus immediately available for the newly hatched larvae, and Curtis (Royal Agricultural Society Journal, 1894, p. 103), so early as 1849, records the abundance of similar larvae and pupae in rotten potatoes, in decaying leaves, dung hills, and putrescent fungi.

Recently attempts have been made to rear these insects artificially, and it was found that during warm weather the life-cycle was regularly completed within 17 or 19 days. During cold weather, however, this period was greatly increased. The number of eggs laid by *P. phalaenoides* seemed to be less—about 60—than was the case with *P. sexpunctata*. Although some 13 successive generations of the former were reared, yet no males were ever seen; while in the latter case the males amounted to 60 per cent. of the number examined.

The larvae (Figs. 15, 16) are whitish, somewhat flattened, transparent grubs, $\frac{3}{4}$ to 9 mm. or $\frac{1}{30}$ inch to $\frac{1}{3}$ inch in length, afterwards becoming brown and less transparent. They possess no legs, but have a well-defined brownish chitinous head and eleven body-segments. The head has well-developed mouth-parts, and two reddish-pigmented spots indicate the eyes (Ocelli), while the other parts are ill-developed.

[1] The number of eggs laid by a single female appears from recent observations to range from 70 to 140.

The first ten body-segments are very much alike, and show dark brown transverse chitinous bands along the back (Fig. 15), the first four segments have two such bands, and the following six three each. Each segment is also provided with characteristic bristles. The final segment is considerably modified, and carries both the anal[1] and breathing (spiracular) appendages.

The larva is extremely voracious and almost ceaselessly engaged in devouring food during the whole period of its existence, this food in the case of the sewage-fed larvae consisting of deposited organic

15

16

17

Psychoda.

Fig. 15. *Eggs and full-grown larva.* The latter shows the dark chitinous plates and lateral bristles; the respiratory appendage is seen from above.

Fig. 16. *Two young larvae* (side view). The larger shows dark head with eyespot and the positions of both the anal and respiratory appendages; the dark transverse lines indicate the positions of chitinous plates.

Fig. 17. *Pupa.* Showing anterior horn-like breathing appendages, eyes, antennae, wings, three pairs of legs, and body segments, the latter usually terminating in a ring of dark bristles. All × 10.

Phot. J.W.H.J.

matter, fungal hyphae and the zoogloea masses which develop upon the filtering material. In this mass of slime the larvae move about with a worm-like motion, assisted by the action of their strong mouth parts. They can remain totally submerged for some considerable time without much inconvenience; food is often obtained whilst the head of the larva is buried in slime, for the respiratory apparatus is situated in the tail and this is raised above the surface, thus securing the necessary supply of air.

The larva after moulting some 3 to 5 times attains a length of

[1] J. A. Dell describes two anal apertures, but the author is inclined to agree with M. Zuelzer's description of a single aperture opening at the apex of the large anal papilla.

about 6 mm., and ceases to eat, the head becomes retracted, the last larval skin is shed, and the insect assumes the pupal form. This takes place while the animal is still buried in the slime, but it soon makes its way to the surface, where it lies with its respiratory appendages exposed.

The pupae are usually shorter (3.5 mm.) and thicker than the larvae and although at first whitish, they rapidly become brown and less transparent. In the pupal stage all the organs of the perfect insect are developed, and the head, thorax and abdomen can easily be distinguished. The wings, legs, etc., are found in a sheath pressed closely and immovably to the body. The head is not at this stage distinctly marked off from the rest of the body, but the compound eyes can be seen through the pupal skin, and from the front of the thorax arise the two long, transversely wrinkled respiratory appendages. The thorax carries the two wings and six legs, while the abdomen consists of seven segments, the last segment having four large spines, which assist the pupa to move about in the filth and so keep the respiratory apparatus exposed to the air. The abdominal segments are provided with numerous bristles, characteristically disposed, and appearing at the lower end of each segment as a complete ring, seen in the figure as a dark band (Fig. 17).

The pupal stage does not last many days, a short period in the life of the insect, and pupae are therefore relatively rare. At the end of this stage the pupa, by the aid of its spines, raises itself above the surrounding slime, its sheath splits longitudinally, and this is soon followed by a lateral rent near the head, forming a T- shaped opening, out of which the mature insect emerges fully equipped for its aerial existence.

The imago or perfect insect is easily recognised by its small moth-like appearance and its uncertain fluttering flight; closer examination reveals the characteristic bead-like joints of the antennae and the hairs which cover both body and wings. The prominent genital armature of the male and the structure of the wings sufficiently characterise the genus *Psychoda*; while the presence of dark patches at the end of the wing nervures serve to identify the species *Ps. sexpunctata*, Curtis (Fig. 14). These dark patches are due to the excessive development of dark coloured hairs, and uninjured specimens normally possess ten such spots on each wing, but the hairs are easily removed by friction, and many insects are found with fewer spots, so that those examined by Curtis may easily have shown only the six from which the specific title originated.

It is possible that the skin irritation which the insects cause in

certain individuals may be due to these hairs entering the pores of the skin. This irritation is apparently not due to bites, inasmuch as the rudimentary mouth parts are short and fleshy and incapable of injuring the skin. In fact the insect appears to pass this stage of its existence without taking food, since none has ever been found in the alimentary canal. Nor can the irritation arise from a sting, as the ovipositor of the insect is not suitably modified. The insects are so light that 2,000 only weigh a gram., or a million of them one pound. They are dioecious, the males being about one-tenth of an inch (2.5 to 3 mm.) in length, and the females about a sixth of an inch (4 to 4.5 mm.), the latter being much more numerous. The female becomes impregnated while resting, and lays her eggs, as already stated, in the moist material so plentiful in the filter, thus completing the life-cycle. The male insects usually hatch out first, followed later by females.

The only other species likely to be confounded with the above is *Psychoda phalaenoides* (L), which is less hairy, darker in colour, and has no wing spots. So closely do the species resemble one another that the *Ps. phalaenoides* of Meigen is apparently from his description *Ps. sexpunctata* of Curtis. Both species are generally to be found on the same filter, but the relative numbers vary at different times of the year. Thus in one case in October last they were all *Ps. sexpunctata*, Curtis, in April only about 20 per cent. were of this species, while in June they were all *Ps. phalaenoides*.

The difficulty of accurately identifying the eggs, larvae, and pupae of the two species will be readily realised, and in the plates illustrating these stages it should be mentioned that they were obtained from a filter on which at the time only *Ps. phalaenoides*, L., were to be found.

From this brief life-history it may be gathered that it is only in the larval stage that the fly plays any part in sewage purification. During the whole of this stage it is actively and voraciously at work devouring and breaking down the solid matters which have been deposited or developed from the sewage, and although the destructive power of a single larva may be almost negligible, yet the combined effect of the myriads present in a sewage filter must have a very appreciable result.

It is only in the final stage that the insect is liable to cause nuisance, and this is no mere sentiment, for the agency of house-flies as disease carriers is now well recognised, and it will be readily understood that these sewage flies, coming as they do directly from excremental matter, may easily carry with them germs of such diseases as diarrhœa or typhoid, but the following experiments with *Psychoda* show that their capabilities in this direction may not be so great as might be imagined.

From each of three collections containing a few hundred flies, twenty were emulsified, and a proportion of the emulsion, corresponding in the amount to the bulk of two flies, was plated on neutral-red-bile-salt-lactose agar.[1] Further, in order to locate any particular infected portions of the flies, two were dissected, the heads, bodies, and legs, and wings being plated separately. The plates were incubated for 48 hours at 37° C., but no presumptive colonies of *B. coli* appeared. The flies in two of these collections were killed, with a minimum amount of chloroform and ammonia respectively, in order to avoid unnecessary damage during transit, while the flies in the third collection had been kept alive until used for the experiment.

In further experiments flies were obtained directly from the moist filtering material by shaking them into the cover of a Petri dish, and were allowed to walk or fly over the surface of a neutral-red-bile-salt-lactose agar in the dish, which was incubated for 48 hours at blood-heat (37° C). It was found that although the flies left many hair-marked tracks on the medium, yet no colonies (presumptive *B. coli*) developed along these tracks. During incubation all the flies perished, and it was observed that in a few cases red colonies developed around the dead bodies, and in the case of flies taken lower down from the sides of the filter, only two or three of these colonies were seen. Others observed on the dish were obviously caused by infected filter material, a dark particle of which was visible as the nucleus of each colony.

These experiments lend support to the statement that the mature fly does not feed at all, and suggest that the danger of their carrying infection may be somewhat remote, but it would be unfair to make any definite statement on this point until the experiments have been frequently repeated.

The appearance of the insect in such numbers as to create a nuisance necessitates conditions favourable to all its stages; for the egg stage, the presence of moisture; for the larval stage, a plentiful supply of suitable food containing organic solids and moisture; for the pupal stage, favourable situations in which it may lodge and from which it may escape in the winged form; and for all stages a plentiful supply of oxygen.

The excessive development of flies naturally attracts a large number of enemies which prey upon them. Among these are insectivorous birds, such as swallows and wagtails; spiders often weave webs which entirely surround the filters, while the dipterous insect *Spathio-*

[1] This substance is used as a primary medium for isolating *Bacillus coli* and allied species; the delicacy of this test will be realised from the fact that 1 c.c. (20 drops) of sewage usually contain 100,000 such bacteria.

phora hydromyzina, Fn., often kills in a frenzied manner large numbers of *Psychodae*. The presence of masses of fungal hyphae in the dead bodies of these flies suggests the possibility of fungal attacks, such as are known to occur in the ordinary house-fly. Besides these direct enemies there are indirect means of attack, such as is afforded by the presence of snails, leeches, worms, "*Podura*" and beetles, which consume the food of the larvae, and it is noteworthy that when "*Podura*" is plentiful *Psychoda* is scarce. The reduction of the amount of colloidal and suspended matter in the tank effluent exerts a similar influence and should be carried as far as practicable; this may often be done by the aid of careful chemical precipitation.

(*b*) The Water Springtail.

Achorutes viaticus (Linn.), Tullb.

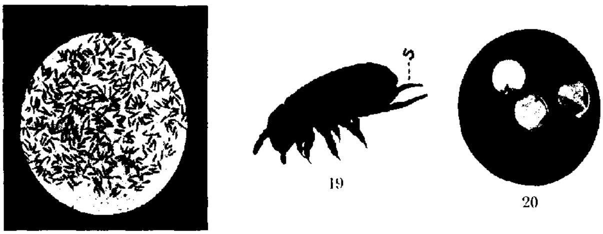
These small wingless insects, which were referred to as "*Podura*," are found on some filters quite as abundantly as the sewage fly, *Psychoda*, but as previously stated, the two insects seldom appear together in profusion.

Springtails occur as bluish-black masses, most evident on small pools of ponded sewage on the filters or on the surface of a humus tank, where at first sight they remind one of small soot particles floating on the surface of the liquid. They may also be found in great profusion on the moist surface of the filtering material, often giving it a bluish-black appearance, and on drying masses of sewage sludge. Each insect is about 2 mm. or $\frac{1}{12}$ inch in length (see Fig. 18).

When closely watched, the insects are seen to be constantly in motion, either crawling on the surface of the water, or, if disturbed, making sudden jumps, sometimes several inches in length. Although resting on the surface of the water they are never wetted by it, and if a stick be immersed near a patch of them they are at once dispersed, but reassemble as soon as the stick is withdrawn. This movement is not due to any alarm but merely to a physical cause, namely, the distortion of the water surface by the wet stick. The water is not level where it meets the stick, but, from capillary attraction, runs for some considerable distance up the wetted surface, and thus the insects are temporarily placed on an inclined plane, down which they at once glissade to the general water level, and *away from* the stick. That the motion is due to the distortion of the water surface is readily proved by smearing the stick with vaseline and repeating the experiment, when they at once appear to cluster round the stick because the greasy end now depresses the water surface so as to form an inclined plane down which the insects glissade *towards it*.

A very interesting experiment is to place several of the insects with a little water in a narrow vessel having high perpendicular sides; here again because of the capillary attraction the water surface is not level, but slopes up the sides of the vessel; consequently the insects become huddled together near the centre of the vessel, and although they make numerous attempts to disperse by jumping, yet whenever they alight near the water's edge they slide back again, and are thus kept crowded together in the centre.

Podura aquatica (Fig. 19) has often been reported as occurring on sewage filters, but it is doubtful if such records are correct, since the insects recently found in localities given for *Podura* have, on detailed examination, proved to be *Achorutes*. They are common on the



18 19 20

Achorutes viaticus (Linn.), Tullb.

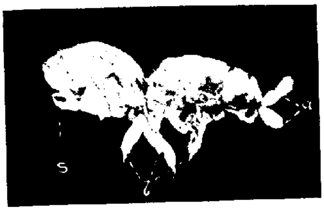
Fig. 18. Group of insects (natural size).
Fig. 19. *Podura aquatica* showing how the spring *(s)* projects backwards beyond the body. × 25.
Fig. 20. Eggs of *Achorutes viaticus* (Linn.), Tullb., showing separation of ruptured outer integument and the developing embryo. × 25.
Phot. J.W.H.J.

sewage works at various places in the West Riding, at Harrow-on-the-Hill, and at Stratford-on-Avon, and all have been found to possess the double-clawed feet which characterise the genus *Achorutes* and distinguish it from *Podura*. Moreover, most small water-springtails are generally regarded without detailed examination as *Podura aquatica*; whereas authentic records of this insect are comparatively rare, and in one instance at least the sewage works' manager reports *Podura* while the local entomologist records *Achorutes viaticus* for the same situation. Some authors have noticed the shortness of the "spring" in the insect found on sewage filters, and have wrongly referred it to *P. tullbergii*, Lubbock.

Characteristics.—*Achorutes viaticus* is a-metabolous, that is, it undergoes no larval or pupal changes. The eggs (Fig. 20), which are whitish and sub-globular, measure 0.2–0.25 mm., or 0.01 inch in

diameter, and are therefore relatively large for the size of the mature insect. They occur either singly or in clusters of 15 or more, and are to be found in the interstices of the top few inches of the filtering material, usually in close proximity to the numerous whitish skin-casts of the insects. As incubation proceeds, the differentiation of the various parts of the embryo becomes more and more marked, the outer integument becomes brown, eventually ruptures and separates, leaving an inner white and more oval envelope containing the embryo, which at the end of a few days emerges as a little fully-formed insect.

The period of incubation and number of eggs incubating naturally vary with the season of the year, and although insects hatch out in the depth of winter and may be found in large numbers on filters even after these have been covered with snow for several days, yet they are most



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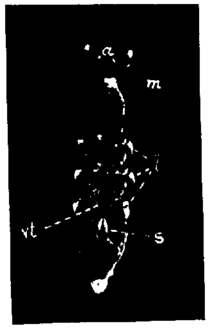


22

Achorutes viaticus (Linn.), Tullb.

Fig. 21. Moult or skin-cast. × 25.
Fig. 22. Ventral view of insect showing position of ventral tube (vt), and forked spring (s) when the latter is flexed up to the abdomen. × 25.

Phot. J.W.H.J.

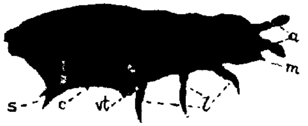
abundant in warm weather, and judging from the number escaping with the effluents from sewage filters, the maximum is reached between June and August.

Within a few hours of birth the insect can both walk and jump, and from this time onwards it undergoes no further metamorphic change, but simply increases in size and vigour, until when mature it measures 2 mm. (0.08 inches) in length, about 10,000 of them weighing one gram, or over 4 million to the pound.

During this period of growth the skin of the insect is shed repeatedly and the cast skins (Fig. 21) may be seen as whitish particles wherever *Achorutes* is abundant. The rate at which moulting occurs

must necessarily vary with many factors, such as the age of the insect, season of the year, amount of food, etc. From observations made during November on 12 young specimens the moulting was so rapid that 12 cast skins were obtained within 48 hours. In casting the old skin the slit through which the insect emerges usually extends along the ventral groove as far backwards as the ventral tube; immediately after the moult the insect is often much paler in colour, being at times almost white, often mauve or pale purple.

The mature insect (Figs. 22, 23, 24) is usually of a glaucous deep blue-black colour, but as previously stated it may vary from almost pure white, through mauve and purple to blue-black. The under surface is often mottled with yellowish or lighter coloured patches.



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Achorutes viaticus (Linn.), Tullb.

Fig. 23. Lateral view showing spring *(s)* extended backwards. × 25.
Fig. 24. Dorsal view showing various organs and general covering of hairs and bristles. × 25.

Phot. J.W.H.J.

Habits and Distribution.—The species under review is not usually very active, and it was perhaps for this reason that the genus received the title of *Achorutes* (Gr. not dancing). It may at times be found in profusion on damp walks, or on moist decaying animal or vegetable matter throughout the year. It is perhaps the most common and widely distributed species of the genus. Schaeffer mentions that it occurs in Siberia, Norway, Russia, Denmark, Britain, Spitsbergen, Greenland, and California in the Northern Hemisphere, while it has been recorded from the sub-antarctic regions of South America, and recently from two small islands south of New Zealand. It may therefore be fairly reasonably termed a cosmopolitan species.

Axelson, in his work on the *Apterygotenfauna Finlands,* has

classified the Apterygota according to the situation in which they are found, and this method is well calculated to emphasise the outstanding characters of any species. *Achorutes viaticus* occurs only in 4 out of his 12 types of fauna, and three of these are situations characterised by the abundance of food, viz.: (1) *Humus fauna* among dung, etc.; (2) *Littoral fauna* both of fresh and salt water; (3) *Water-surface fauna*. It has also been found in (4) the *Winter fauna*, showing that the species is fairly capable of tolerating cold. Another interesting point brought out by this classification is the fact that it is a lowland form, no record having ever been obtained of its existence in mountainous districts. Although so very widely distributed, its identity does not appear to have been recognised by any authority dealing with its appearance and function on sewage filters, and it is only when the records of specialists on the group Collembola are consulted that any adequate idea of its concurrence is obtained.

Carpenter mentions (Proc. Roy. Phys. Soc., Vol. XIV, p. 225, and Mins. of Plans and Works Comm., Edinburgh, 11th April, 1906, p. 334), that he found these insects in millions on the seashore in Scotland amongst decaying seawrack; again on a wall near a newly manured turnip field; at South Queensferry on seawrack, and at Comiston on putrid turnip. Other observers have seen them in England on a footpath at Stratford-on-Avon Sewage Works (Collinge, Thysanura and Collembola, Birm. Nat. Hist. and Phil. Soc., 1910, pp. 6 and 7); at Berkhamstead about a rubbish heap where decaying mangels had been thrown, and on the water draining from it; on a garden footpath (Collinge and Shoebotham, The Apterygota of Hertfordshire, Jour. Econ. Biol., 1910, Vol. v, pt. 3, p. 99); in Ireland near a manure heap at Portadown (J. W. Shoebotham, Ann. and Mag. Nat. Hist. Ser. 8, Vol xiii, January, 1914). Professor Carpenter also states that they are present in the Dublin Sewage Outfalls. The above situations agree remarkably well with those given by Axelson in his faunal classification.

Food Supply.—The insects must be regarded as scavengers, and Prof. Carpenter in his report upon the occurrence of similar insects in the water hydrants of the City of Edinburgh says: "As to the food the present species in common with many others subsist chiefly if not entirely on decaying vegetable (and perhaps also animal) matter, fungi, and confervae."

Mr. H. D. Bell, at Stratford-on-Avon, has attempted to measure the amount of carbon dioxide and ammonia evolved from a given weight of the living insects. He corroborates the view that the principal food is the slimy material on the filtering medium, and states that its

removal from sprinkler filters by the insects prevented "ponding" and gave an increased amount of nitrates in the effluent. Further, on filters where ponding had occurred it was remedied by artificial inoculation with *Achorutes*.

The specimens obtained from Harrow-on-the-Hill occurred among the green alga *Prasiola crispa*, which has the property of absorbing sewage pollution in a manner very similar to that of the *Ulva latissima* so well known in Belfast Lough. The alga in this manner becomes very rich in nitrogenous substances and constitutes a rich food for such insects.

The dark colour of the insect usually prevents any direct observations being made upon the contents of the alimentary tract, but on two or three occasions—in paler varieties—the whole of the tract has been clearly outlined by the green colour of the ingested *Prasiola*, and from this it appears that the insect at times feeds upon living plant tissue.

Culture Experiments.—During the winter months attempts were made to rear the insects in captivity. At first considerable difficulty was experienced in obtaining a suitable food supply, for bread and similar usual aliments were found unsuitable.[1] Experiments with the green alga *Prasiola crispa* were more successful, but its use was liable to introduce other insects than those under observation, and particularly their eggs, so that it could not be considered satisfactory, while slime obtained from clinker on a percolating filter formed an excellent food supply and could readily be obtained without the above contamination. Small pieces of clinker covered with this slime were rapidly attacked by the captive insects, and the disappearance of the slime, together with the presence of numerous skin-casts on the clinker, left no doubt as to the nature of their food on sprinkler filters. The slime consisted chiefly of *Zoogloea* masses, developing fungal hyphae, and debris which this growth had retained from the sewage. The food supply thus seems to be similar to that of the *Psychoda* larvae on such filters.

In these latter experiments, although the insects were kept alive for some considerable period, yet no noticeable increase in numbers was ever observed; the cold season of the year may perhaps have had some deterring influence on reproduction.

Observations have been made during the past six months upon the occurrence of *Achorutes* on the sewage filters in the West Riding, but no very definite information has yet been obtained to show why on one set of sewage works these insects may be found in myriads, while on another apparently similar they may be scanty in number or even

[1] Mr. G. B. Kershaw has recently employed moist blotting paper for this purpose and found it very suitable (*The Surveyor*, Nov. 13, 1914, p. 397).

absent. The points of difference in the various sewage works taken into consideration have been the nature of the filtering medium, whether slag, clinker or stone; the size of the top layer and its condition as to ponding, the nature of the sewage treated, whether wholly domestic or containing trade refuse; the kind of tank effluent dealt with, whether produced by simple settlement, septic treatment, or precipitation, and whether containing much or little suspended matter. It must be confessed that it has not been ascertained what are the controlling factors which favour or prevent the prevalence of *Achorutes*. It should, however, be borne in mind that these observations have been made during the winter months, when the insects are often few, but so far as they have gone they tend to support the view previously expressed that the two kinds of insects do not occur in profusion on the same filters, and generally *Achorutes*, unlike *Psychoda*, prefers situations where the sewage is ponding.

(5) Other Dominant or Sub-dominant Organisms.

Almost any organism may, under suitable conditions, develop into a dominant or sub-dominant species; most of these species have already been reviewed in the ecological associations dealt with in a former section. A few of these associations, although occurring on sewage filters are better illustrated in polluted watercourses, and are therefore treated from this point of view.

The *Colon bacillus* or *Bacillus coli*, as it is sometimes termed—although it cannot develop either in sewage or water to any appreciable extent—belongs to this class, for it is present both in the crude sewage and also in the final effluent; the untreated sewage containing some 100,000 per c.c (20 drops). This bacillus is normally an inhabitant of the intestinal tract, and according to Dr. Houston human excreta contains from 100 to 1,000 millions of these bacilli per gram. The *Colon bacillus* can be readily identified in water even if only present to the extent of 1 per 10 c.c. Its identification therefore constitutes a very delicate bacteriological method of estimating or detecting sewage pollution. Unfortunately, however, there is no means of distinguishing between human and other sources of faecal contamination.

Bacteriological Examination of River Samples.—After a number of determinations had been made it became obvious that the gelatine counts (although giving more characteristic colonies than those on the Agar medium) were apt to be misleading, as at times the purer river waters gave higher figures than those obviously more polluted. This may in part be due to the inhibiting effect of substances

in the polluted waters, as mentioned in the earlier pages of this paper; but upland waters of undoubted purity are capable of yielding unusually large numbers of *uniform* colonies, so that mere enumeration of colonies, without considerable attention to their character, can afford no appropriate basis for comparison among rivers of such widely different quality as those of the West Riding. Eventually it was decided to abandon both these counts, and to extend the investigations into the number and nature of the *B. coli,* which offers a much better and safer criterion of animal pollution.

The variations in the numbers of this bacillus are very marked, but in making comparison between different rivers, or even different portions of the same river, numerous factors should be borne in mind. A gradual reduction in numbers occurs in consequence of sedimentation, and thus a stream polluted in its higher reaches would naturally, if no further pollution occurred, contain less *B. coli* in its lower portion; this is borne out by the numbers generally found at the lowest points of observation on the Rivers Aire and Calder at Methley, and on the River Don at Conisboro'. The numbers are obviously affected by the amount of dilution of any polluting discharge, and of this some indication is afforded by the rainfall. The effect of increased rainfall is to reduce by dilution the numbers found, but on the other hand a flood prevents sedimentation and stirs up deposited solids in the beds of the streams, and this may cause a marked increase in the numbers of these bacilli.

The term *B. coli* includes a group of bacilli, all of which possess certain well-defined primary characteristics, but which may show widely varying secondary characters, some of them liable to be lost, modified, or developed, under change of environment. Without explaining in any great detail the methods employed for separating the general group into its various strains or races, it may be stated that one characteristic most commonly used as a guide is the power of producing fermentation in solutions of various kinds of sugar.

All varieties of the bacillus should ferment both Glucose (Grape sugar) and Lactose (Milk sugar), but some fail to produce this change in Saccharose (Cane sugar), that is they are cane sugar negative, or briefly C.S.N., in contra-distinction to the cane sugar positive, or C.S.P. varieties.

The percentage number of C.S.P. varieties in faecal matter according to Mac Conkey (Journal of Hygiene, Vol. v, page 333) only amounts to 28, the remaining 72 being C.S.N. The *B. coli* hitherto found in the Yorkshire river samples contain 82.3 C.S.P. and only 17.7 C.S.N., whereas Dr. Houston (6th Annual Report, Metropolitan Water

Board, page 40), in the raw waters of the Thames, Lee and New River, finds 63.8, 64.4, and 60.9 per cent. respectively of C.S.N. varieties.

This difference in the sugar fermenting capacity of the *B. coli* found in these rivers compared with those of Dr. Houston is presumably due to the different environment possibly caused by the presence of trade waste. The inimical effect of acid trade waste on this organism will now be dealt with, and considering the very marked effect which it has on the life of this organism, it is only reasonable to suppose that such substances, even in small quantity, have a marked effect on the character of this organism.

Effect of Acid Waste on the B. coli contents of the Bradford Beck. —A sample of the Beck at its junction with the Aire, although obviously very polluted, contained fewer bacteria than the river immediately above, while in the river at some distance below the junction the bacteria were much more numerous than above. The following table will serve to make this clearer:—

Bacteria per c.c. of River Water.

	B. coli.	Bacteria developing on:—	
		Agar at 37°	Gelatine at 20-22°.
River Aire (Baildon Bridge)	730	3,200	60,000
Bradford Beck*	300	2,000	about 2,000 (Covered with mould)
River Aire (Buck Mill)	8,750	39,500	537,000

The reduced bacterial life in the Bradford Beck in the presence of gross sewage pollution was opposed to previous experience and suggested the presence of some inimical substance, probably the sulphuric acid used as a precipitant at Frizinghall Sewage Works, and this suggestion was supported by the presence of numerous colonies of *Oospora lactis*, Sacc., a mould which readily develops in an acid medium.

The two accompanying photographs (Figs. 25, 26) show the appearance of this fungus in Petri dish cultures on prune gelatine after

*Since the samples could not be examined until 18 hours after taking, these figures show a greater reduction than would occur in nature; for during the whole of this time the acid would be operative, whereas in nature dilution—which retards its action—occurred almost immediately below the point of sampling.

two and three days' growth respectively, and also serve to illustrate its relative frequency in the Bradford Beck samples.

A further example of the reduction of bacterial life attributable to the presence of acid was recently observed during an examination of Lupset Beck, near Wakefield. This watercourse receives the discharges from Ossett Spa Sewage Works, consisting of both treated and untreated sewage, a large portion of the latter being composed of acid waste from dyeing and carbonising processes. It was impossible to find *B. coli* in 1 c.c. either of the effluent or of the stream below these works, and even in the crude sewage, which contained excreta, only two colonies per c.c. developed. The mould (*Oospora*) noted in the Bradford Beck, also appeared in the acid samples.

25

26

Fig. 25. *Oospora lactis*, Sacc. Colonies developing from 0·1 c.c. of Bradford Beck water after two days' growth on gelatine. (Half natural size).

Fig. 26. *Oospora lactis*, Sacc. Colonies developed from 0·01 c.c. of Bradford Beck water after three days' growth on gelatine. (Half natural size).

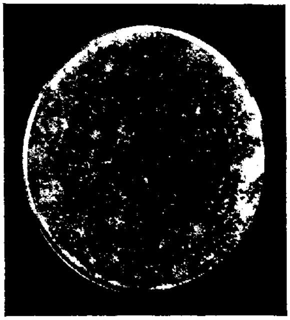
Phot. J.W.H.J.

The photographs (Figs. 27*a*, 28*b*, 29*c*) show the development of this fungus after 48 hours in cultures containing 1 c.c. of (a) crude sewage, (b) water from the Lupset Beck near its junction with the River Calder, and (c) filter effluent from the sewage works. It will be noticed that in culture (*c*), which was slightly alkaline, no growth of the mould occurred, and that the culture dish is thickly studded with numerous colonies of bacteria, whereas on the other two culture plates the colonies are almost entirely overgrown by the fungus.

The growth of the mould *Oospora lactis*, Sacc., under such conditions suggested that it possessed high resistant powers towards

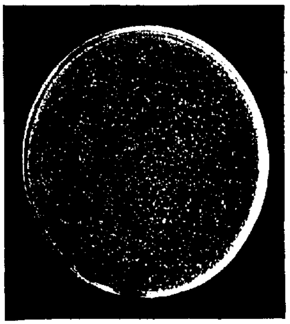
germicides, and this was fully supported by the results given in the table on p. 155.

The medium used in these experiments was a 10 per cent. decoction of prunes, to which 12.5 per cent. gelatine had been added. Nine c.c. of this medium rendered sterile was placed in each of a number of tubes and 1 c.c. of a 0.1, 0.5, and 1.0 per cent., or, of acids and alkalies a 2.0, 10.0, and 20 per cent. solution of the reagent



27*a*

28*b*



29*c*

Oospora lactis, Sacc.

Fig. 27*a*. Petri dish culture from 1 c.c. crude sewage, Ossett Sewage Works. (Half natural size).

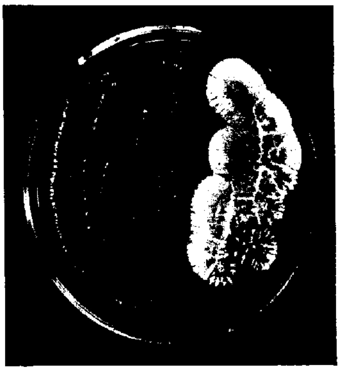
Fig. 28*b*. Petri dish culture from 1 c.c. Lupset Beck water, below Ossett Sewage Works. (Half natural size).

Fig. 29*c*. Petri dish culture from 1 c.c. filter effluent, Ossett Sewage Works. (Half natural size).

Phot. J.W.H.J.

was added, and, after the tube contents had been well mixed by shaking, they were poured into Petri dishes. When the gelatine had solidified each dish was roughly divided on the outside into two parts by means of a grease pencil line, and each half inoculated from one of two previous cultures of the fungus. These cultures, although showing no microscopic difference, exhibited some slight cultural variations, one (the right-hand half in the photographs) being constantly much whiter and slightly more vigorous in growth than the other (Figs. 30, 31).

The table of the results obtained after the use of the various reagents shows, as might be expected, considerable differences; formalin having a much stronger action on this organism than either mercuric chloride or carbolic acid. The amount of acid and alkali required to prevent germination is about fifty times as great as the



30 31

Oospora lactis, Sacc.

Fig. 30. Petri dish culture on medium containing 10 parts per 100,000 of carbolic acid. (Half natural size).

Fig. 31. Petri dish culture on medium containing 50 parts per 100,000 of carbolic acid. (Half natural size).

Phot. J.W.H.J.

amount of formalin; while in a medium with 1 per cent. of either hydrochloric or sulphuric acid, or sodium carbonate, growth is prevented. With 0.2 per cent. ammonia (NH_3) a peculiar liquefying growth occurred, while with a similar amount of sodium carbonate (Na_2CO_3) there was a very luxuriant growth of *Oospora*. It is possible that with a liquid medium containing well established cultures widely different results might be obtained, but the above results sufficiently illustrate the resistance which this organism offers to antiseptics.

Effect on various Reagents on the growth of *Oospora lactis*, *Sacc.* (after 48 hours).

Re-agent.	Parts per 100,000.	Amount and character of growth.	Parts per 100,000.	Amount and character of growth.	Parts per 100,000.	Amount and character of growth.
Carbolic Acid	10	Good growth	50	Growth but less than preceding	100	No growth. Needle track showing
Mercuric Chloride	10	Good growth	50	No growth ...	100	No growth
Formalin	10	Good growth	50	No growth ...	100	No growth
Hydrochloric Acid	200	Good growth	1000	No growth ..	2000	No growth
Sulphuric Acid	200	Good growth	1000	No growth ...	2000	No growth
Ammonia	200	Deep seated liquefying growth	1000	Very slightly liquefying	2000	No growth
Sodium Carbonate	200	Very good growth	1000	Very slightly liquefying	2000	No growth

Considerations such as the above show that very small quantities of special substances may very greatly influence the flora and fauna of a stream (see U.S. Department of Agriculture, Bureau of Plant Industry, Bulletins Nos. 64, 76, and 115; also Surveyor, 1913, pp. 833, 869), and that a purely chemical standard for sewage effluents cannot be considered sufficient. For example, the small amounts of acid which so favour the growth of *Oospora* in the water of the Aire would not be taken into account in the suggested chemical standard of the Royal Commission on Sewage Disposal, and there are other substances which, even if present in very small amounts, may temporarily defer the decomposition of organic matters and thus vitiate the Commission's test of the absorption of dissolved oxygen, which in a large measure depends upon bacterial action.

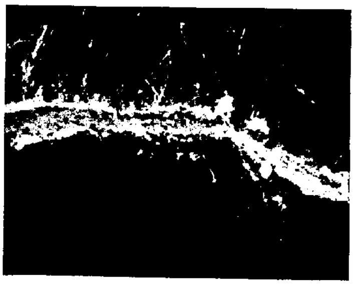


Fig. 32. *Thiothrix nivea* (Rabh.), Win., developing around decaying *Carchesium* stalk. (Canal bye-pass, Horbury). × 100.
Phot. J.W.H.J.

Thiothrix nivea in the River Aire.—The polluted condition of the Aire below Leeds causes great nuisance; in October, 1911, the river at the Thwaite Gate Ferry had a distinct odour of sulphuretted hydrogen, and the stones near the water's edge were thickly covered with a white growth. This proved to be one of the so-called "sulphur bacteria," and was identified as *Thiothrix nivea* (Rabenh.), Winogr. (Figs. 32, 33). This organism has apparently not been previously recorded in Britain, and has presumably been confounded with other sulphur organisms such as *Beggiatoa*. *Thiothrix* also flourishes in the bye-pass on the Calder and Hebble Canal at Horbury, where it forms a white felted mass attached to the free-floating portions of aquatic plants (*Potamogeton*) and animals.

Thiothrix nivea is found as a delicate white covering on stones, algae, or submerged aquatic plants. It usually occurs in polluted

liquids which contain sulphuretted hydrogen, and when associated with certain algae is classed by Kolkwitz and Marsson as a *Mesosaprobe*.

Although it is found in polluted liquids it develops best in situations where a certain amount of aeration is possible, as was illustrated in the River Aire, where the growth was restricted to a narrow zone along the bank the gentle lapping of the water naturally assisted aeration. Its marked development and frequent occurrence in the aerated water of the canal bye-pass at Horbury lends further support to this view. Although in this case the presence of sulphuretted hydrogen could not be demonstrated.

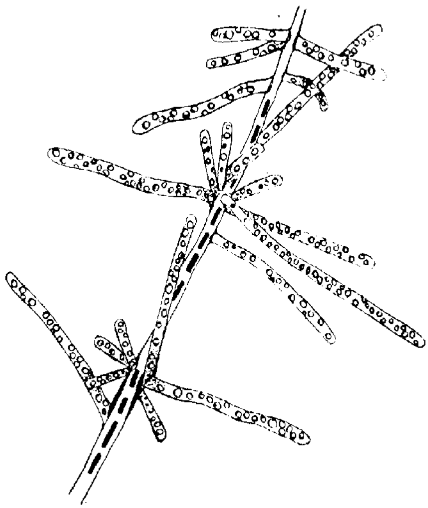


Fig. 33. *Thiothrix nivea* (Rabh.), Win., developing around a fungal filament of *Sphaerotilus natans*. (Canal bye-pass, Horbury).
Del. J.W.H.J.

Thiothrix belongs to the group of white sulphur bacteria, *Beggiatoaceae*, and may be distinguished from the closely allied genera by the following characters:—

Beggiatoaceae.

Filaments of uniform thickness, free swimming, gonidia wanting *Beggiatoa*.

Filaments of uneven thickness, attached, developing motile rod-like gonidia - - - - - *Thiothrix*.

Filaments contained in a common gelatinous envelope *Thioploca*.

Thiothrix filaments are non-motile, being 1.7 μ thick, and tapering in older specimens to 1.5 μ. They are usually attached by a somewhat thickened gelatinous base, 2.0—2.5 μ in diameter, and contain numerous sulphur granules, which in older or starved specimens disappear, when the organism may be confounded with *Sphaerotilus natans*, Kütz.

Dominant Algae.—Where land is used for the final treatment of sewage "ponding" is liable to occur, and in such cases green coloured organisms often appear in such profusion as to colour the liquid.

Species of *Chlamydomonas* and *Euglena* are amongst the most frequent, and in one instance a large area was similarly coloured by *Richteriella botryoides*; chiefly of the *fenestrata* variety. This alga has only once been previously recorded in the British Isles—Lough Beg, Ireland—and it is doubtful if the variety has ever been obtained before in these islands. Its appearance, therefore, in such profusion is the more remarkable.

Dr. Letts has shown that the marine alga, *Ulva latissima*, so common in the "sloblands" of Belfast Lough, possesses in a remarkable degree the property of rapidly absorbing soluble nitrogenous sewage matters. This same property is also exhibited by the green alga, *Prasiola crispa*, which, under suitable conditions, develops both in the thalloid and filamentous forms on the surface of sewage filters. The latter form often occurs as green filaments between the "setts" of the quiet streets in our towns, while the former is frequent on the bare moorland, where it is entirely dependent upon human source for its nitrogenous supply.

Oxidation of Sewage without the aid of Filters.

No account of modern methods of sewage disposal would be complete without some reference to the recent experiments which have been made in this direction with "activated" sludge. In 1908 Dr. H. Maclean Wilson suggested the possible presence of a sewage-coagulating enzyme in the "humus" from a sewage filter, and although the author was unable to isolate successfully an enzyme, yet ample evidence was obtained of the coagulating effect of this "humus" on sewage matter.

Dr. Fowler, when in America, saw a laboratory experiment in which sewage was purified by long continued "blowing" of air through the liquid. The addition of "humus" was suggested, and after continued "blowing," this "humus" or mud became more and more efficient or active, so that now a mixture of 25 per cent. of "activated" mud and 75 per cent. of sewage, after one or two hours' blowing produces a liquid which when settled is comparatively clear

and odourless, thereby affecting a purification of 75 per cent. or more, moreover, the liquid seems particularly suited to the requirements of fish life. The mud settles rapidly and is of a brownish colour, containing some 96 per cent. of water, and dries well; the dry residue contains the very large percentage of 4.6 of nitrogen.

Microscopically, the bulk of the mud shows nothing very characteristic, but the repeated presence of *Opercularia* suggests an association which I have noticed in rapidly flowing water where *Zoogloea ramigera* was the dominant organism, and from experiments now in operation it seems possible that zoogloea, assisted by other minute organisms chiefly of animal origin, may be responsible for the rapid purification thus effected. That such minute animal life, *i.e.*, protozoa, rapidly destroy nitrogenous substances is proved by the increased amount of nitrogen and its derivatives observed when soil is partially sterilised, and the protozoa are thus destroyed.

Whatever may be the *modus operandi* of this purification, the process has been developed along lines of natural biological evolution; each improvement in the method of aeration has produced a corresponding increase in the number and the variety of organisms which were capable of participating in the oxidation of the polluting organic matter, and has thus given an increased efficiency. In this respect it may be well to remember the importance which Professor Frankland originally attached to aeration, and how in the successive stages from land—which is often subject to sewage sickness—the development proceeded to contact beds, which provide a more certain aeration, and then to intermittent filters providing constant but scarcely perfect aeration, and lastly to the stage where the medium is dispensed with and the purification concentrated upon the organisms themselves in the presence of an adequate air supply. Although the bulk of the mud may be relatively small when compared with the material of a filter, yet, owing to its fine state of division, the active surface presented to the liquid is enormous, and purification is consequently much quicker.

If this process can be successfully developed it appears to offer a simple solution to the question of fly and other troubles, for with a few hours of this treatment the putrescible portion of the pollution would be so far oxidised that the food supply of flies, etc., would be destroyed, and with this the disappearance of their troublesome myriads would be assured.

In all biological purification systems the question of the admission of trade refuse to sewers is a very serious one. Attention has already been directed to the disturbing influence which these liquids may exercise upon the ordinary process of purification. However, con-

sidering that in many instances the greater proportion of the pollution proceeds from such sources, it follows therefore that any system to deal efficiently with this problem must of necessity be capable of dealing with the bulk, at any rate, of the trade refuse. Generally speaking, trade refuse, if mixed with ordinary sewage in reasonable quantity, presents no serious difficulties in treatment, as the two liquids often inter-react and thereby assist precipitation. With the more objectionable discharges—where the deleterious effect upon the filter is out of all proportion to the quantity discharged—it would perhaps be more economical to treat them separately, or only admit them to sewer after efficient primary treatment.

In conclusion, no ecological work of this kind has hitherto been attempted in Britain, and it is only recently that any serious attention has been given to the study of the flora and fauna specially adapted to the purification of sewage. While many of these forms are undoubtedly well known to most biologists, there are, however, others, which—although of frequent occurrence—are practically unknown to the British Flora. This is especially noticeable among the lower fungi, and the following list will give some idea of the species likely to be encountered in such work. Some difficulty has been experienced with regard to the previous records of these organisms, and those marked * are apparently new to Britain :—

Schizomycetes.

**Zoogloea ramigera*, Itzshn and vars.; *Sphaerotilus natans*, Ktz.; *S. roseus*, Zopf.; *S. fluitans*, Schka.; *Cladothrix dichotoma*, Cohn.; *Gallionella ferruginea*, Ehr.; *Chlamydothrix ochracea* (Ktz.), Mig.; **Thiothrix nivea* (Vauch), Win.; *Beggiatoa alba* (Vauch). Trev.; **B. leptomitiformis* (Menegh), Trev.; **Chromatium okenii* (Ehr.), Perty; **Hillhousia mirabilis*, G. S. West; and var. **palustris*; **Clonothrix fusca*, Roze.

Eumycetes.

Fusarium aurantiacum, Sacc.; **Sporotrichum lanatum*, Wallr.; **Mucor circinelloides*, V. Tiegh; **Acremonium spicatum*, Bon.; *Dematium pullulans* de B.; **Aspergillus fumigatus*, Trev.; *A. niger*, V. Tiegh; *A. grisues*, Lk.; *Sachsia suaveolens*, Lind.; *Thamniduim vulgaris*, Fr.

Considerable difficulty is experienced in the identification of these fungi because the nature of their habitat usually precludes fructification. Recourse must therefore be had to (*a*) subcultures, and (*b*) recognition by purely vegetative characters. Subcultures are very liable to contamination from bacteria, spores, etc., and growth in artificial media

is often disappointing. Vegetative forms on the other hand are less characteristic, but more readily observed and are free from many of the serious disadvantages of cultivation methods.

Considering the difficulty of direct identification of such material, the accuracy of many of the previous records is open to grave suspicion. Even the Royal Commission on Sewage Disposal has not given much assistance in this respect, and in the Eighth Report (Vol. II, Appendix) the oft-repeated remark that "grey algal growth" occurs in various streams, possibly suggests hazy ideas of the confines of algae and fungi.

Much therefore remains to be accomplished; apart from the direct economic aspect of this problem, the study of the phyto-zoological distribution in relation to food supply is one of vital interest to all biologists.

In connection with this paper, I desire to express my thanks to Dr. H. Maclean Wilson for many kind suggestions and also for the use of blocks; to Prof. G. H. Carpenter, Dublin, Messrs. R. S. Bagnall, Walter E. Collinge, and J. W. Shoebotham for specimens and assistance in the identification of Collembola; to W. Falconer for the identification of spiders; to Miss A. Lorrain Smith, and Messrs. W. B. Grove and C. Crossland for assistance and suggestions with regard to the Eumycetes; also to Mr. P. H. Grimshaw for the identification of several dipterous insects. Thanks are also due to many surveyors, and managers of sewage works, and to the Staff of the West Riding Rivers Board for kind assistance in obtaining specimens for identification.

Summary.

1. The evolution of sewage treatment by means of land, chemical precipitation, tanks, contact beds, sprinkler filters, and, lastly, by mechanical aeration in the presence of "biologically active" mud.

2. The sewage problem is attributable to the increase in size and number of towns; the discharge of obnoxious trade wastes; these factors are further accentuated by the introduction of the water-carriage system of sewage disposal.

3. Organisms and their various functions in sewage purification.

4. Organisms and their relation to the pollution.

5. *Sphaerotilus natans* and *Zoogolea ramigera*.

6. Resumé of ecological factors and associations observed in filters and streams.

7. The Sewage- or Moth-Fly (*Psychoda*).

8. The Water Springtail "Podura" (*Achorutes viaticus*, Tullb.).

9. Other dominant or sub-dominant organisms.
   (a) *Colon bacillus* as an index of pollution: its presence and variable character in river waters.
   (b) Effect of acid on the colon-bacillus content of river water and development of *Oospora lactis* in such liquids.
   (c) Resistance of *Oospora* towards germicides.
   (d) Effect of small quantities of special substances on the flora and fauna of streams.
   (e) Notes on the occurrence of *Thiothrix nivea, Euglena, Chlamydomonas, Richteriella, Ulva* and *Prasiola.*
10. "Activated" sludge method of treating sewage.
11. Treatment of trade refuse on biological filters.
12. List of new or uncommon fungi isolated from polluted waters.

CORRECTIONS.

The following errors occurred in printing part 1 of this paper:—

Page 111, line 27, for Dupre *read* Dupré; line 29, for Höfer *read* Hofer; line 30, for Dibden *read* Dibdin.

Page 117, line 7, for Vaüch *read* Vauch.

Page 118, col. B., line 4, for rebissonii *read* brebissonii; line 5, for cryptosephala *read* cryptocephala; line 15, for Surrella *read* Surirella.

Page 119, col. B., line 13, for Carchsium *read* Carchesium; line 19, for vulgari *read* vulgaris.

Page 120, line 28, for Botrytococcus *read* Botryococcus.

Page 121, line 19, for Polysaprolic *read* Polysaprobic.

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NOTES ON *TELEPHORUS RUFUS*, L. AND ITS VARIETIES.

By OLGA G. M. PAYNE, M.Sc.,

Late Research Assistant, Department of Agricultural Entomology, University of Manchester.

(With Plate VII).

On account of their great variability in colouration, the Telephoridae present many difficulties to the systematist, and it is mainly with the view to establishing definitely one at least of the species of *Telephorus*, that this research work was undertaken. During the year 1911, several apparently similar *Telephorus* larvae were obtained from a field, near the Entomological Laboratory of the Manchester University, at Fallowfield. The adults bred out from these larvae varied, resembling both *T. darwinianus*, Shp., and *T. lituratus*, Fall., and it was found impossible to determine to which species the larvae belonged. It was therefore suggested that in the year 1912 as many as possible of these larvae should be reared, in order to find out if the adult differences were due to different types of larvae, or whether the above specimens were merely colour variations of one species.

In order to carry out these investigations, a number of Telephorid larvae were obtained from the locality mentioned. Before being placed in the breeding tins, they were carefully examined so that any differences (if present) might be noted. The larvae were found to differ considerably in size, but this seemed to be due rather to varying degrees of maturity than to actual specific differences.

Colour variations were also to be noted, some of the larvae being a much darker brown than others. There were, however, intermediate degrees of colour between these two extremes of light or dark. No structural differences were to be observed to coincide with those of colouration. In order to find out if the colour variations of the larvae in any way determined those of the adult, the colour of each larvae was carefully noted on the breeding tin. It was found later that there was absolutely no coincidence between larval and adult colour variations. The adults obtained on breeding out the larvae varied considerably in colour and also in size, the colour variations being much more marked than those of size. The chief colour variations to be noted were, a light form, a dark form, and an intermediate form between those.

[Journ. Econ. Biol., December, 1914, vol. ix, No. 4.]

Connecting up these three varieties were several transitionary forms, making almost a complete colour series. The presence of these transitionary forms is a strong argument in favour of the view that only one species is here being dealt with.

The beetles were forwarded to the British Museum, where Mr. Gahan kindly examined them and compared them with the specimens there. After careful examination he came to the conclusion that all the beetles reared belonged to a single species. Fig. 2 (Pl. vii) is a typical example of what is commonly known as *T. lituratus*. The light form represented in Fig. 1 Mr. Gahan considered as corresponding with the continental *T. rufus*, L.

In the *Catalogus Coleopterorum Europae* (1906) *T. lituratus*, Fall., is given as a variety of *T. rufus*, L. It is noteworthy that the Linnean name of *rufus* is older than Fallen's specific title of *lituratus*. The darker form, of which Fig. 3 is an example, Mr. Gahan considered as agreeing in colour with typical *T. darwinianus*, Sharp. He was not, however, sure that this dark form is to be considered identical with the species of Sharp (Trans. Ent. Soc. Lond., ser. 3, Vol. v, 1886, pp. 436-37), owing to differences in habitat and to certain differences in size and structure. In *T. darwinianus*, Sharp, the antennae are proportionately not quite so long, especially in the male, as in the dark variety of *T. lituratus*. The pronotum is relatively a little broader and the elytra shorter than in the latter species. This opinion was endorsed by Mr. Halbert, who was good enough to examine the beetles and compare them with those in the Dublin Museum.

The great variability of colour of *T. lituratus* is noted by Fowler, whose description is given below (Coleoptera of the British Isles, Vol. IV, 1890, pp. 138-39).

"*T. lituratus*, Fall. (*rufa*, L; *maculicollis*, Steph.); *bicolor*, Panz.). This species varies very much in colour; as a rule it is testaceous, with the vertex of the head, an irregular marking on the disc of the thorax, and the greater part of the abdomen and legs black; the antennae are more or less dusky with a lighter base; occasionally the thorax and legs are entirely testaceous, and rarely the elytra are black; head finely punctured, antennae varying in the sexes; thorax about as long as broad, obsoletely punctured, anterior angles rounded, posterior angles almost right angles; elytra finely sculptured, with distinct traces of raised lines; legs rather robust. L. 6½—9 mm."

"Male with antennae much longer than in the female, without impressed lines on the central joints, third joint about twice as long as second."

"Female with antennae shorter, third joint of antennae only

slightly longer than second; elytra not covering apex of the abdomen; seventh ventral segment sinuate at each side, central lobe sharply incised at the apex. On Umbelliferae, etc., moderately common and generally distributed throughout England and Wales, and probably Ireland; very common in some parts of the Midlands; less common further North; Scotland, scarce, Tweed, Forth and Tay districts."

At the beginning of the above extract it will be seen that *T. rufus*, L., is here considered by Fowler as synonymous with *T. lituratus*, Fall., while as before noted continental authors consider *lituratus*, Fall., as a variety of *T. rufus*, L., the latter being the older name.

T. rufus can be distinguished from its variety *lituratus*, Fall., in the total absence of any dark marking on the head, thorax, tibiae, femora and the first joint of the antennae. The elytra are also not quite so dark as in the var. *lituratus*, and they are at the same time more rounded at the tips. The *darwinianus* variety appears to correspond with the "rare" form, in which the elytra are dark, in Fowler's description of *T. lituratus*. They can, however, hardly be considered as rare, as over thirty per cent. of the beetles obtained had blackish elytra.

In addition to mentioning the black form of *T. lituratus*, Fowler (p. 139) includes a definite species, *T. darwinianus*, Sharp. His description is given below.

"*T. darwinianus*, Sharp. This species, which was introduced by Dr. Sharp, is closely allied to *T. lituratus*, but may be known by its broader and stouter build, much shorter and stouter antennae, of which the third joint in both sexes is not much longer than the second; the thorax, moreover, is proportionately longer and the elytra proportionately shorter; the general colour is darker, the elytra being often of a more or less dark brownish-testaceous colour, especially towards the apex; it is possible that the species may be a form of *T. lituratus*, but it appears to be more distinct than others, which are regarded as quite separate. L. 8—10 mm.

"Found on the coast under seaweed, and not, apparently, on plants or herbage:—Scotland, local, Solway and Firth districts (Firth of Forth at Aberlady, etc.); Dr. Sharp has observed that some of the females have the elytra and antennae deformed (reminding one of the apterous forms in some of the neighbouring genera), and appears to be in great favour with the males; this fact and their peculiar habitat makes it seem possible that the beetle is a form of a neighbouring species, probably *T. lituratus*, which has been altered by its environment." Some additional localities are given in Fowler's supplementary volume (Vol. vi, 1913, p. 277).

The question now remains, is the dark form which was bred out to be considered identical with the species *T. darwinianus*, Sharp, or is it to be considered only as Fowler's dark variety approximating to *T. darwinianus?* In Fig. 3 it has been called var. *darwinianus*. If the darker specimens were found only under estuarine conditions it would seem highly probably that there is a very interesting example of the formation of a new species under the action of a different environment. The fact, however, remains that the darker forms are produced in fair numbers under inland conditions.

With regard to the slight structural difference it does not seem that very much importance can be attached to them, as throughout the var. *lituratus* there are small structural variations in each beetle. Only one instance of a deformed female has been observed.

Without further observation on estuarine species it is of course impossible to do more than doubt the validity of Sharp's species, though it seems very probable that this dark variety *darwinianus* of *T. rufus* and the *T. darwinianus* of Sharp are identical.

It may be that estuarine conditions, warmth and moisture tend to produce the dark colouration to the exclusion of the other types. In which case the presence of dark adults among inland forms could be explained by assuming that the larvae most susceptible to the variable conditions of heat and moisture in the soil tended to produce the darker adults.

Without further experimental work it is, however, impossible to assert more than the opinion that *T. lituratus*, Fall., and *T. darwinianus*, Sharp, are to be regarded as varieties of *T. rufus*, L. A dissection of the male genitalia might possibly shed welcome light on the question, as it has been recently proved of value in the allied genus *Chauliognathus*. Time and opportunity, however, have prevented any further work being prosecuted.

Dr. D. Sharp, Mr. C. J. Gahan, of the British Museum, Mr. J. N. Halbert, of the Dublin National Museum, and Mr. J. Ray Hardy, of the Manchester Museum, have been good enough to assist me in the identification of the species.

EXPLANATION OF PLATE VII.

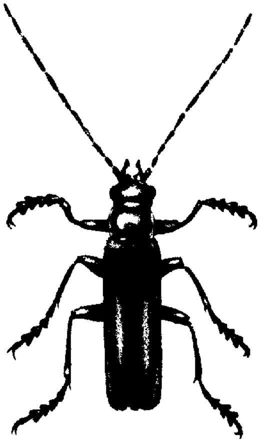
Illustrating Miss Olga G. M. Payne's paper on "*Telephorus rufus*, L., and its varieties."

Fig. 1. *Telephorus rufus*, L. ♂ × 4.

Fig. 2. *Telephorus rufus*, L. var. *lituratus*, Fall. ♂ × 4.

Fig. 3. *Telephorus rufus*, L. var. *darwinianus*, Sharp. ♂ × 4.

N.B.—The fore-legs in each figure have an unnatural extension which is not exhibited in living examples.



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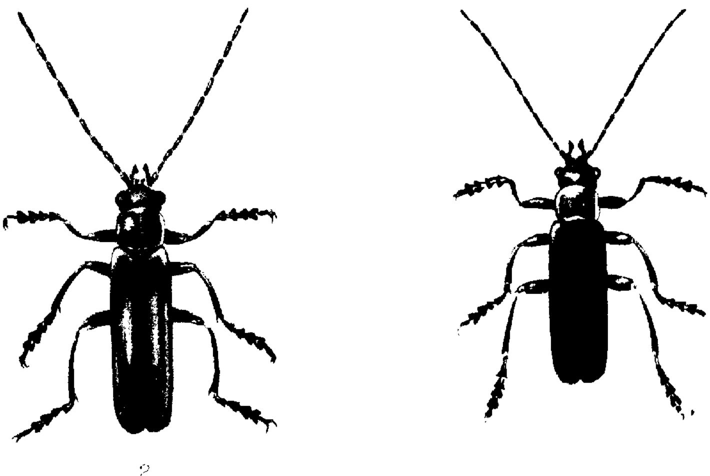

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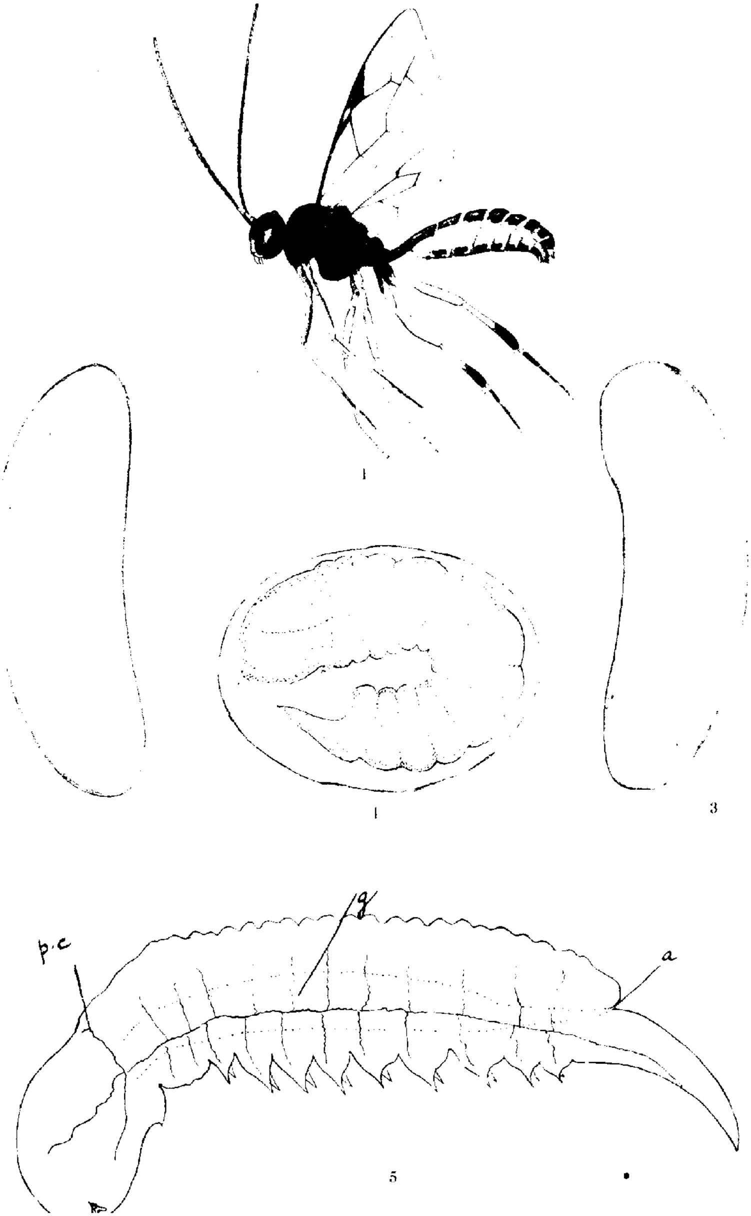
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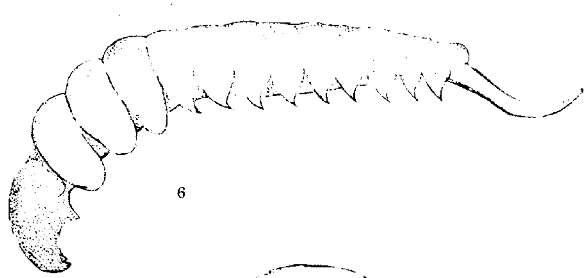

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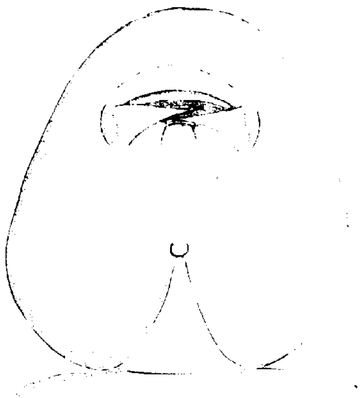

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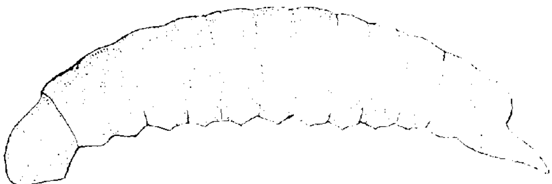

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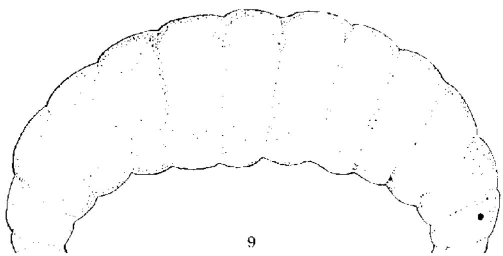

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REVIEWS.

COCOA. By Dr. C. J. J. van Hall. Pp. xvi + 515, and 140 figs. and map. London: Macmillan & Co., Ltd., 1914. Price 14s. net.

In this excellent series of works dealing with tropical agriculture, Dr. van Hall's treatise must rank as one of the best yet issued, for it not only presents an interesting and exhaustive account of all appertaining to the subject of cocoa, but it is also stamped with the hall-mark of a wide and practical knowledge of the subject.

After a brief historical account of the use and culture of the cocoa plant and its gradual spread from Mexico to other countries, the geographical distribution and climatic conditions relative to it are dealt with. Especially valuable are the chapters dealing with the chemistry of cocoa and cocoa soils, and the botanical characteristics of the cocoa plant, as also that on the varieties of cocoa. Two chapters are devoted to the technical side of cocoa cultivation, which may be read with profit by all concerned with the subject, they are replete with sound and practical advice, nothing seems to have been overlooked that would in any way prove useful to the planter.

A very useful summary is given of our present state of knowledge of th. diseases and enemies of cocoa, and a really comprehensive survey on cocoa-growing countries, if for no other reason, this last feature is sufficient to make the book invaluable.

Dr. van Hall's work forms an excellent compendium on an all-important subject, containing as it does a large amount of very practical matter, the outcome of long experience and study, and a considerable quantity of statistical matter of the highest importance.

THE COCO-NUT. By E. B. Copeland. Pp. xiv + 212, 23 figs. London: Macmillan & Co., Ltd., 1914. Price 10s. net.

Professor Copeland's work, whilst dealing mainly with the coconut industry of the Philippines, will be read with interest and profit by all connected with the industry. "The behaviour of the coco-nut is intelligible," we are told, "in the light of the knowledge of its physiology, and surely in no other way"; in spite of this statement, however, the present work contains only a very short chapter of eighteen pages on the subject.

The two most important chapters, in our opinion, are those dealing with diseases and pests, and field culture, both are very complete, and contain an amount of information not to be found in any similar work. In the author's opinion, coco-nut raising is profitable, and its future is safe, no other business seems to him quite so certain as this one to continue for a term of decades to pay large profits at all times. For this desirable end it is essential that the planter should be up-to-date

in all concerned with this industry, and there is much in the work before us that will prove of great value to the intelligent grower. Science with practice is evidently the author's rule, and the business side of his subject is kept prominently in the fore. He has had ample personal experience to warrant him in expressing positive opinions on many debatable matters which make his work a distinct acquisition to the literature on the subject.

IMPURITIES OF AGRICULTURAL SEED. By S. T. Parkinson and G. Smith. Pp. 105 and 153 figs. London: Headley Bros., 1914. Price 3s. net.

The scope and aim of this little handbook are excellent, as also most of the illustrations. The subject matter of the first forty pages might very well have been fuller, nevertheless they have been written with care and lucidity.

With the aid of this work and a good magnifying glass, the intelligent grower will be able to examine his seed samples with profit.

It is a pity that for so many species of plants obsolete names are used, and that specific names are spelt with capital letters.